National Aeronautics and
Space Administration

Document #: GHAPS-DOC-017
Revision: Basic
Effective Date: 24 September 2014

John H. Glenn Research Center
Cage Code No.: 1QFP5
21000 Brookpark Road, Cleveland, Ohio 44135

Gondola for High Altitude Planetary Science Project (GHAPS)

RFI for High Accuracy Pointing System

Basic Release

Change History

Revision *(For draft documents, use numbers)*	**Effective Date**	**Description**
Basic	RFI Announcement Date 24 September 2014	Final release version

Table of Contents

Table of Figures

Table of Tables

1 Description

1.1 Requestor

The National Aeronautics and Space Administration (NASA) John H. Glenn Research Center (GRC) in support of the GHAPS (Gondola for High Altitude Planetary Science) program office is seeking information on how an interested contractor could develop a *High Accuracy Pointing System* that would be capable of providing precise and controlled articulation of an optical telescope assembly.

1.2 Scope-of-Request

THIS IS A REQUEST FOR INFORMATION (RFI) ONLY. This RFI is issued solely for information and planning purposes – it does not constitute a Request for Proposal (RFP) or a promise to issue an RFP in the future. This request for information does not commit the Government to contract for any supply or service whatsoever. Further, NASA GRC is not at this time seeking proposals and will not accept unsolicited proposals. Respondees are advised that the U.S. Government will not pay for any information or administrative costs incurred in response to this RFI; all costs associated with responding to this RFI will be solely at the interested respondees expense. Not responding to this RFI does not preclude participation in any future RFP, if any is issued. If a solicitation is released, it will be synopsized on the Federal Business Opportunities (FedBizOpps) website. It is the responsibility of the potential respondees to monitor these sites for additional information pertaining to this requirement.

2 Background

2.1 Overview

The GHAPS project concepts-of-operations requires a high accuracy pointing capability that will enable a gimbal system to articulate an optical telescope assembly (OTA) to point and track inertial targets with sub-arc-second accuracy. The pointing system is identified as a *high-accuracy* system in that it must maintain the line-of-sight pointing to an ECI (earth centered inertial) target to sub-arc-second accuracy, while suspended on a balloon gondola that progresses through a disturbance attitude profile. The following figure illustrates how the gimbaled pointing system fits within a cascaded three tier segments of the pointing. These tiers include:

1. Outer-loop station-keeping[1]
2. Inner-loop OTA pointing
3. Fine steering mirror image stabilization

The broad station-keeping responds to commanded yaw and gondola disturbance (pitch and roll). Exiting this loop, the station-keeping is assumed to resolve the program track yaw command to within 0.1 degrees (360 arc-seconds). Progressing to the inner-loop, the OTA pointing system processes sensor measurements to resolve the final pointing target to the desired 0.5 arc-second accuracy. These sensors may include one or more star trackers and platform rate gyros. The gathered sensor information will be processed to support the computation of the final auto-track correction, doing so while maintaining loop stability and loop performance (among other aspects identified in baseline requirements).

The following paragraph discusses loop partitions and how the respondee is to address these and loop coupling. This RFI addresses the need for an inner-loop control architecture, as identified in this figure by a **green box**. The respondees' system may be partitioned exactly as indicated in this figure. That is, they may have designed a high accuracy pointing system that operates inside of a station-keeping loop. However, it may be the case that the respondees' system is based on an integration with an outer loop station-keeping; this is identified in this figure by an **orange box**. In this case, the respondee should describe their *integrated* dual-loop system and **not** attempt to parse the inner loop out for the sake of the RFI response.

Finally, the fine steering mirror control loop (pictured lower right) is not part of this RFI. However, it is likely that the inner-loop will need to communicate with the fine steering mirror loop to assess saturation and available control authority. Therefore, it is desirable to have some provision to link the state information in these loops (loop coupling). The loop coupling will be two-way (duplex), as indicated in the figure, of which information is requested.

[1] The term station-keeping generally refers to maintaining a target longitude-latitude satellite location. Its context is broadened in the present RFI to refer to the maintenance of a flight attitude to facilitate outer-loop pointing control.

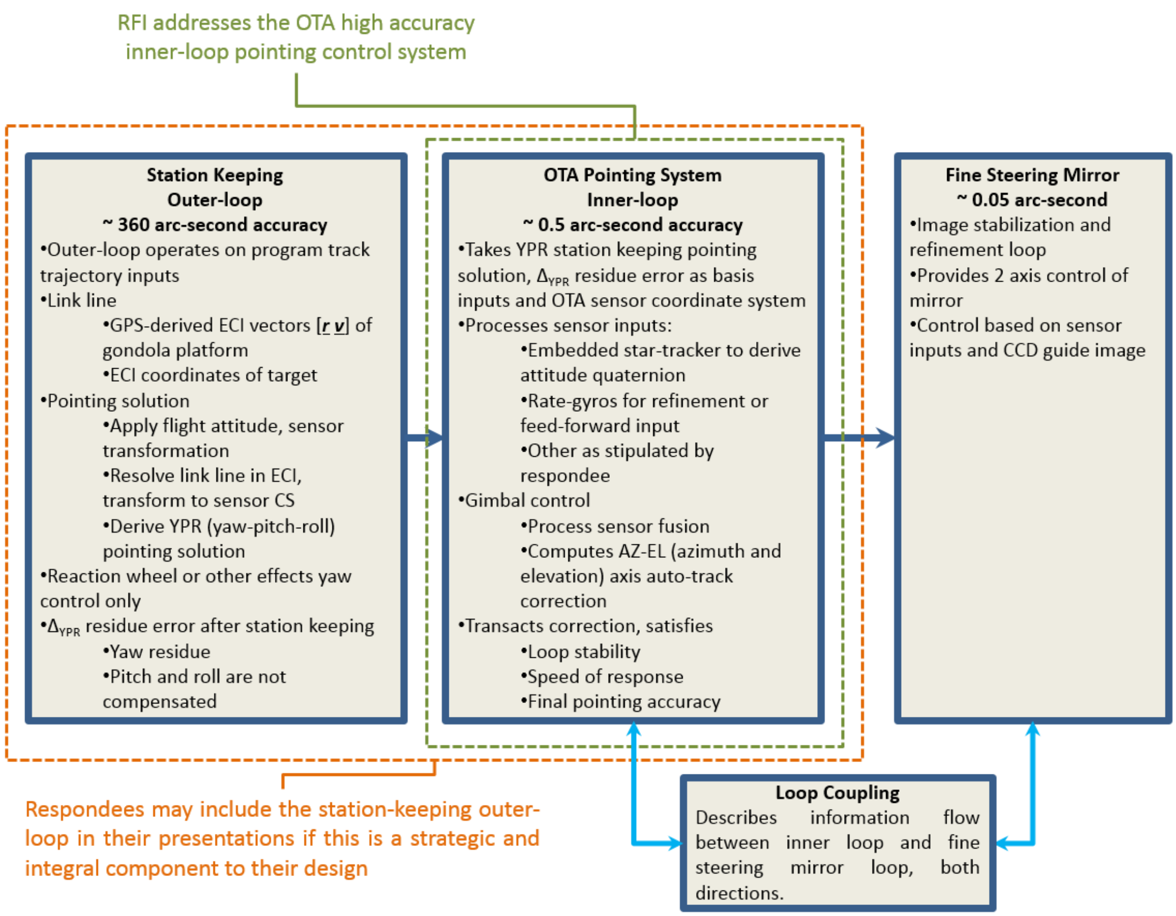

Figure 2-1 Pointing system showing cascaded three-tier loop architecture

2.2 Specifications

The following section defines basic specifications for the target payload and the inner-loop OTA pointing system, for which information is being sought. This information is categorized in Table 2.1. This table does NOT define a formal requirements specification. Instead, it is intended as an aid to respondees in formulating a response that best suites the needs of the GHAPS program.

2.3 Delivery Period

As noted in the Timeframe below, the GHAPS program will need to take stock of the first unit on date 03/01/2016.

Table 2-1 System specifications

Specification	Value or Range	Comments
Dynamic Pointing Accuracy	0.5 arc seconds (1.389E-4 degrees)	Considered to be a RSS (root sum squared) 1σ dynamic pointing accuracy, while operating in closed-loop mode. Control system should maintain a hold on the target ECI (earth centered inertial) location to this accuracy.
Settling time	60 seconds (1 minute)	Time to acquire the target ECI location, upon AZ-EL (azimuth and elevation) command, to the specified pointing accuracy
Hold time	10 minutes	Time required to maintain the specified dynamic pointing accuracy, when on ECI target, after settling
Target Payload Envelope	1.4 meter	Diameter of the OTA and ancillary structure that is to be housed in the mechanical gimbal interface. Note the OTA diameter is nominally 1 meter and incurs and additional 0.4 meters to accommodate insulation thickness. Note that this is a notional maximum payload envelop. Note the pointing systems may be adopted to hold smaller diameters devices.
Target Payload Mass	250 kg (551.2 lbm)	Mass of the OTA that is to be housed in the mechanical gimbal interface. Note that this is a notional maximum payload mass. Note the pointing systems may be adopted to hold smaller mass devices.
Moment of Inertia	349.0 kg m^2	Transverse moment of inertia, assumes a cylinder with 4 meter length, diameter of 1 meter, at the target payload mass
Attitude Input Disturbance Rate	0.00349 Radians/s (0.2 degrees/s)	This is considered to be the 1 sigma (1σ) angle rate-of-change on RSS input error from the yaw, pitch and roll axes of the gondola that must be compensated for. This is considered a disturbance input that remains after station-keeping yaw control.
Loop Time Step **Loop Frequency**	0.1 seconds 10 Hz	This is the minimum time-step for all digital elements of the control system. The respondees' control system may operate on a sub-integration step, but it is understood that all solution data elements (see below) are provided on a 10 Hz loop frequency (inverse of the time step). Note the respondees' control system may operate at a **smaller** loop time step as necessary.
Feed-forward Data	ECI position and velocity vectors, nominal flight attitude	Gondola position and velocity vectors, in ECI coordinates, and nominal flight attitude YPR (yaw-pitch-roll) will be **provided to** the respondees' control system, updated at the loop frequency.
Derived Sensor Data	Attitude quaternion	Attitude quaternion derived from a star tracker solution, will be **provided by** the respondees' control system, updated at the loop frequency. The quaternion will be resolved in the gondola coordinate

		system which can be referenced to the OTA via fixed transformation. This information may be shared with the fine-steering mirror control (see loop coupling).
Derived Sensor Data	Gimbal axis-rates	Gimbal axis-rates, derived by rate-gyros, will be **provided by** the respondees' control system, updated at the loop frequency. This information may be shared with the fine-steering mirror control (see loop coupling).
Feedback Data	Gimbal angle and angle-rates	It is assumed that the respondees' control system will include conventional gimbal axis angles (AZ-EL) and axis angle-rates as feedback elements. It is desired to obtain and provide this information to the outside control elements for overall control which are described above to be station-keeping and fine steering mirror control (see loop coupling). It is understood that the respondees' control system may not actually utilize the gimbal angles as feedback in closed-loop mode, but for reasons maintained above, it is still necessary to have this information.

3 Requested Information

3.1 Overall System Concept Abstract

The respondee should describe the overall system concept and design in abstract form. This should be just a thematic description to allow reviewers to get an immediate sense of the approach taken to solve the problem.

3.2 System Architecture Diagram

The respondee should describe the system architecture **graphically** in block diagram format. The goal of this section should be to convey the overall system concept rapidly in graphical form. This diagram should show the breakout of major systems and how the information flows across component or system lines. This information can be notional and need not address a physical piece of hardware. For example, a mechanical gimbal does not need to be shown separately, but instead could be included as part of a larger integrated assembly.

3.3 Interfaces

The respondee should describe the various interfaces to their candidate system according the following subdivision.

3.3.1 Mechanical

This would include a description of mounting interfaces and any special considerations for holding the gimbal assembly. The respondee should indicate if their system can accommodate the nominal OTA diameter and mass (see target payload mass).

3.3.2 Electrical

This would include a description of the type of power required to operate the gimbal assembly and if special power conditioning is required, e.g. AC, DC, voltage and current levels.

3.3.3 Thermal

This would include a description of the thermal management approach, either passive or active cooling. For passive cooling, the respondee should indicate if their system requires special thermal shielding or a clear view of space in a zenith or off-zenith direction. For active cooling, the respondee should indicate if their system requires connection to a pumped thermal loop or other thermal bus and if their design includes this loop and bus.

3.3.4 Processor and CPU Grind

This would include a description of the computer processor required to propagate the gimbal control system solution and other systems such as sensor processing and health monitoring. The respondee should indicate if the processor would be part of the delivered solution. The respondee should also indicate what CPU grind is required to solve these tasks in a real-time basis. The CPU grind is defined as the wall clock time to process one time step of the computational task during the processing of the inner pointing loop control. The specification of a candidate processor, along with the CPU grind, will allow the extension of this data to future systems where the real-time operating system and computer boards have not yet been selected.

3.4 Control System

The respondee should describe the control system of their candidate system according the following subdivision. As indicated in the loop architecture figure, the respondee is encouraged to include graphics to aid in the review of the material.

3.4.1 Convention

The respondee should indicate the type of control system architecture. An example of the type of specifications would be conventional feedback with PID, IMC (internal model control), and fuzzy controller. These examples are not necessarily desired nor conclusive - just notional.

3.4.2 Loop Design

This would include a description of the loop design such as one loop nesting in another (e.g. velocity inside of position command loop). Ideally this will be conveyed in the System Design Architecture.

3.4.3 Feed-Forward Data

To aid the respondee, the specifications table includes a reference to feed-forward data. The feed-forward data is considered to be provided to the control loop at the loop frequency. This includes ECI target location, and basic station-keeping attitude. If the respondees' control system requires additional feed-forward information, (e.g. attitude-rate information) this would be indicated in this section.

3.4.4 Derived Sensor Data

The respondee should describe derived sensor data required to form the control system response solution. As described in the specifications table, the derived sensor data are data elements processed by sensors in order to form the sub-arc-second pointing solution. This will likely include a star-tracker derived attitude quaternion and gimbal-rate information, but the respondees' control system may employ some other sensor measurements and sensor fusion to achieve the desired pointing accuracy. These should be described as such.

3.4.5 Feedback Elements

This would include a description of the feedback, as applicable, for each of the loops identified above. The respondee should indicate what feedback is required to close the loop on the pointing system (see below for more information).

3.4.6 Loop Coupling

The respondee should describe how the necessary loop coupling will be transacted. This could be a simple as indicating the feedback elements and sensor data will be ported to external control elements.

3.5 Performance

The respondee should describe the nominal performance of their candidate system according the following subdivision.

3.5.1 Open-Loop Stability

This would describe the open-loop gain and phase margins on either of the gimbal position control loops. Simulation results would be sufficient.

3.5.2 Closed-Loop Bandwidth

This would describe the maximum frequency for -3 dB roll-off of the position control subject to input disturbance.

3.5.3 Acquisition Time

This would describe the time required for the control system to reject *large*[2] platform errors as would be encountered during purposeful (program track) yaw station-keeping and disturbance pitch and roll. This excludes the settling time (see below) to acquire the final inertial target at sub-arc-second accuracy. It may be the case that there is no distinction between acquisition and settling, i.e. the control system works from large to small errors without changing modes.

3.5.4 Settling Time

This is the delta time, after acquisition, that is required to settle the pointing to the final sub-arc second target.

[2] The notion of large platform errors refers to the pointing residue left over from station-keeping yaw attitude response. During this response, the control system would need to be able to process the large value angle errors and articulate the gimbal to the desired target acquisition angles. Large errors imply degrees, in contrast to small errors i.e. arc-second and sub-arc-second.

3.5.5 Dynamic Pointing Accuracy

This is the maximum RSS (root sum square) of the gimbal Δ_{AZ} and Δ_{EL} pointing error (delta AZ and delta EL) during settling. This would convey the final pointing accuracy, i.e. the pointing error ε would be defined by:

$$\varepsilon = \sqrt{\Delta_{EL}^{2} + \left(\Delta_{AZ} \cdot \cos\left(\alpha_{EL}\right)\right)^{2}}$$

3.5.6 Modes

This is the first and second modal frequencies of the closed-loop dynamics. This would be measured by a DFT (discrete Fourier Transform) of the closed-loop position response. This data would be used to assess any resonance with the fine steering mirror or the gondola structural modes. Simulated results could be supplied in the place of actual data. If simulated or actual modal information are not yet available, the respondee should indicate as such.

3.6 Consumables

The respondee should describe finite consumables of the candidate system according to the following subdivision.

3.6.1 Power

This would describe the steady state operating power requirements under nominal pointing hold conditions.

3.6.2 Momentum

This would describe a limitation of momentum buildup in a reaction wheel if such a system is employed. This will probably only be relevant if the respondee is addressing an integrated outer and inner-loop pointing control system (see loop integration).

3.6.3 Thermal

For open active systems, this would describe any consumables related to the thermal system. This might also include phase-change materials if employed that may need to be recharged.

3.7 Operations

The respondee should describe operations elements of the candidate system according to the following subdivision. This can be done in a narrative form.

3.7.1 Deployment

This would describe how the system is deployed from a launch configuration such the OTA and gimbals are taken out of latched, stowed condition.

3.7.2 Target Tracking

This would describe how the system is set up to operate from target-to-target. That is, after completing a target tracking, the control system must prepare and process the next target, after a purposeful station-keeping control. This aligns more with Concept-of-Operations statement (not part of the present RFI), but is helpful to understand how the control system would be operated.

3.7.3 Stowing

This would describe how the system is setup for stowage prior to balloon jettison and gondola return. Opposite to deployment, the narrative should describe how the OTA and gimbals are stowed back to a captured, locked position.

3.8 Rough Order of Magnitude (ROM)

3.8.1 Unit Cost

The respondee should describe an estimated ROM for a single unit cost.

3.8.2 Development Time

The respondee should describe an estimated ROM for a single unit development time.

3.9 Past Performance

The respondee should provide a narrative of past development and performance on pointing systems that are related to the current system.

4 Responses

4.1 Method

Interested parties are requested to respond to this RFI with a white paper.

4.2 Format

White papers are to be prepared in a Microsoft Word for Office 2007 compatible format.

4.3 Due Date and Contact

White papers are due no later than 24 October 2014, 08:00 EST. Responses shall be submitted via e-mail only to Brian S. Huth, Lead Contract Specialist, brian.s.huth@nasa.gov.

4.4 Proprietary Information

Proprietary information, if any, should be minimized and MUST BE CLEARLY MARKED. To aid the Government, please segregate proprietary information. Please be advised that all submissions become Government property and will not be returned.

4.5 Content - Section I

The respondee should file information according the following topical areas. The number of pages in Content - Section I of the white paper shall not be included in the page limitation specified above, i.e., the page limitation applies only to Content - Section II of the white paper

4.5.1 Contact

Name, mailing address, overnight delivery address (if different from mailing address), phone number, fax number, and e-mail of designated point of contact

4.5.2 Recommended contracting strategy

Specify the recommended contracting strategy.

4.5.3 Business Type

Specify the business type (large business, small business, small disadvantaged business, 8(a)-certified small disadvantaged business, HUBZone small business, woman-owned small business, very small business, veteran-owned small business, service-disabled veteran-owned small business) based upon North American Industry Classification System (NAICS) code 541712 – Research and Development in the Physical, Engineering, and Life Sciences. Please refer to Federal Acquisition Regulation FAR 19 for additional detailed information on Small Business Size Standards.

4.6 Content - Section II

Content - Section II of the white paper shall make a best attempt to answer the topical areas outlined in the Requested Information.

4.7 Content - Section III

The respondee is encouraged to expound outside the Requested Information areas if they feel the material is relevant to a proper evaluation. Accordingly, Content – Section III is dedicated to ancillary information that the respondee may wish to provide to support the evaluation.

4.8 Page Limit

The page limit for this RFI is defined by content-section, as highlighted in the following table. Note that this defines a maximum number of pages. The respondee is encouraged to provide direct and concise responses and limit extraneous information.

Table 4-1 Content page limit

Content Section	Topical	Page Limit
Content - Section I	Respondee Information	No limit
Content - Section II	Requested Information	15
Content - Section III	Ancillary Information	10

5 Industry Discussions

NASA GRC or its NASA GRC support contractors may or may not choose to meet with respondees. Such discussions would only be intended to get further clarification of potential capability to meet the requirements, especially any development and certification risks.

6 Questions

Questions regarding this announcement shall be submitted in writing by e-mail to the Contracting Officer, Brian S. Huth, Lead Contract Specialist, brian.s.huth@nasa.gov. Verbal questions will NOT be accepted. Questions will be answered by return email. Accordingly, questions shall NOT contain proprietary or classified information. The Government does not guarantee that questions, received more than two weeks after the RFI announcement date, will be answered.

7 Summary

THIS IS A REQUEST FOR INFORMATION (RFI) ONLY to identify sources that can provide a *High Accuracy Pointing System*. The information provided in the RFI is subject to change and is not binding on the Government. The NASA GRC has not made a commitment to procure any of the items discussed, and release of this RFI should not be construed as such a commitment or as authorization to incur cost for which reimbursement would be required or sought. All submissions become Government property and will not be returned.